An Economic Evaluation of the *Moneyball* Hypothesis

Jahn K. Hakes*
Albion College

and

Raymond D. Sauer**
Clemson University

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*Hakes: Department of Economics & Management, 109 Robinson Hall, Albion College, Albion, MI 49224. Phone: 517-629-0650; e-mail: jhakes@albion.edu.
** Sauer: The John E. Walker Department of Economics, 222 Sirrine Hall, Clemson University, Clemson, SC 29634-1309. Fax: 864-656-4192; Phone: 864-656-3969; e-mail: sauerr@clemson.edu. We thank John-Charles Bradbury, Dennis Coates, Mike Maloney, Dave Studeman, Bob Tollison and all others who offered their comments and assistance in various forums.

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Abstract

Michael Lewis's book, *Moneyball*, is the story of an innovative manager who exploits an inefficiency in baseball's labor market over a prolonged period of time. We evaluate this claim by applying standard econometric procedures to data on player productivity and compensation from 1999 to 2004. These methods support Lewis's argument that the valuation of different skills was inefficient in the early part of this period, and that this was profitably exploited by managers with the ability to generate and interpret statistical knowledge. This knowledge became increasingly dispersed across baseball teams during this period. Consistent with Lewis's story and economic reasoning, the spread of this knowledge is associated with the market correcting the original mis-pricing.

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> "'When I started writing I thought if I proved X was a stupid thing to do that people would stop doing X,' he said. 'I was wrong.'" – Bill James in 1984 Baseball Abstract, quoted in Lewis (2003, p. 93)

> "If you're an owner and you never played, do you believe Voros McCracken or Larry Bowa?' The unemployed former paralegal living with his parents, or the former All-Star shortstop and current manager who no doubt owned at least one home of his own." Lewis (2003, p. 241)

I. Introduction

Imagine a good produced primarily with labor. The particular skills involved are unique to the production of this good. The skills are also multi-dimensional, and individual workers have varying quantities of skill in each dimension. The associated labor market is well known. It receives daily attention from the print and broadcast media, along with periodic in-depth analysis from academic economists. Indeed, a case could be made that more is known about pay and performance in this market than any other labor market in the American economy.

Into this milieu strides a financial reporter who makes the following claim: the valuation of skill in this market is grossly inefficient. The inefficiency is so large that a former worker with mediocre talent and two quantitative analysts could exploit it to great effect. The firm that hired them was able to out-manage and out-produce most of the competition while operating on a shoestring budget. This is the tale told by Michael Lewis (2003) in *Moneyball*, about the use of innovative thinking and statistical analysis in the management of the Oakland Athletics baseball club.

As the characterization above makes clear, the thesis of *Moneyball* is economic at its core, and indeed is potentially refutable. Yet "the biography of an idea," as Lewis (2004) called his work, does not verify itself, however convincing the argument. We examine the argument here. We cast it in refutable form, and test it with elementary econometric tools. We find that Lewis' claims bear close scrutiny. In particular, we confirm that the baseball labor market exhibited significant inefficiency in recent years. This inefficiency was sufficiently large that knowledge of its existence, and the ability to exploit it, enabled the Athletics to obtain a substantial advantage over their competition. We also find that Lewis' timing was impeccable. The ideas in *Moneyball*, belying protestations from entrenched interests in the baseball world (Lewis, 2004), spread with sufficient speed that baseball's labor market no longer exhibits the "*Moneyball* anomaly."

Sports often generate ideal conditions in which the choices of market participants can be observed and studied. The value of this is becoming more widely appreciated. Notable studies which illustrate the range of economic issues where data from sports can lend insight are Robert E. McCormick and Robert Tollison (1986), William O. Brown and Raymond D. Sauer (1993a, 1993b), and Pierre-Andre' Chiappori, Steven D. Levitt, and Timothy Groseclose (2002). These papers analyze how the likelihood of punishment affects crime (fouls on the basketball court), the effects of psychology and information on market prices (point spreads for NBA games), and strategic optimization in a repeated game (the puzzling unwillingness of penalty-kick takers to shoot the ball down the middle, when goalkeepers almost always dive one way or the other).

The present paper's contribution may be thought of as a depiction of particularly clear case of mis-pricing, accompanied by successful innovation and subsequent

adjustment in the labor market. We document this by evaluating the measures of offensive productivity discussed in the book, and measuring their impact on game outcomes. We then assess the valuation of skill in baseball's labor market. Consistent with the claims made in *Moneyball*, important batting skills were undervalued in the marketplace during the initial periods that we study. However, a diffusion of the knowledge discussed in the book subsequently took place. We find that the anomaly disappears as members of the Athletics' organization were hired to run competing franchises.

II. Measures of Offensive Productivity and their Contribution to Winning

A. Measures of Skill

The most common measure of skill is the *batting average*, i.e. the ratio of hits to total at-bats. The batting average is a crude index. By weighting singles and home runs the same, it ignores the added productivity from hits of more than a single base. Much better is the *slugging percentage* (total bases divided by at-bats) in which doubles count twice as much as singles, and home runs twice as much as doubles. Gerald Scully's (1974) demonstration that baseball players earned a small fraction of their marginal revenue product under the reserve system used slugging percentage as a measure of productivity. Nevertheless, both the batting average and slugging percentage ignore potentially relevant dimensions of batter productivity. Sacrifices and walks, for example, are often productive and occasionally crucial, but are ignored in both measures. Indeed, since a fundamental element of batting skill is the ability to avoid making an out, the failure to

account for walks is a serious omission.[1] These flaws in the batting average were understood as early as the 1950s, when Branch Rickey[2] argued for the importance of "on base percentage," i.e. the fraction of plate appearances in which the player reached base successfully (Lewis, 2003, p. 71).[3]

The statistic du jour among statistically-minded followers of the game is "OPS," which is the sum of on base percentage (O) and slugging percentage (S). It has long been known among this group, dubbed sabermetricians, that linear combinations of these two percentages are very highly correlated with runs scored, the primary objective of an offense.[4] The essence of the *Moneyball hypothesis* is that, while the importance of on base percentage was well understood by sabermetricians, the ability to get on base was seriously undervalued in the baseball labor market.

B. Contribution to Winning

We confirm that OPS is a powerful indicator of baseball success by estimating linear regressions of winning percentage. Using performance data over five seasons from 1999-2003, Table 1 demonstrates that OPS-based measures explain 88% of the variance in winning percentage across teams. Models 1 through 3 in Table 1 all confirm the symmetry between offense and defense in producing wins for on-base percentage and

[1] An inning in baseball is composed of three outs; once those are used up, any situational advantage derived from the number of men on base prior to that point is lost. Outs are the ultimate scarce resource in baseball, hence the ability of a batter to avoid them – which necessarily entails advancement towards home plate – is of fundamental importance.

[2] Rickey was general manager of the Brooklyn Dodgers in the 1940s, and is best known for breaking the color barrier in baseball by signing Jackie Robinson.

[3] Andrew Zimbalist's (1992) critique of the Scully model presciently noted that on base percentage makes an important contribution to statistical models of team winning percentage.

[4] The construction of OPS is similar to the "runs created" formula devised by Bill James (2001; 330), hence the high correlation between the two. James coined the moniker sabermetrics from the Society for American Baseball Research (SABR), of which James was an early member.

slugging percentage individually, and for the combined OPS statistic. Model 1 shows that team and opponent on-base percentages explain 82.5% of the variance in winning percentage, while team and opponent slugging percentages explain a slightly lower 78.6%. Model 3 demonstrates that crudely adding on-base percentage to slugging percentages to create OPS improves the explanatory power of the regression to 87.1% of variance.[5]

The final column of Table 1 imposes the restriction that, loosely speaking, the contribution of Yankee bats to a Yankee victory is equivalent to the contribution of Yankee bats to their opponent's defeat. This model is used to assess a claim made in *Moneyball*(Lewis, 2003, p. 128) that, contrary to conventional wisdom, on base percentage is more important than slugging percentage on a point-for-point basis. The coefficients in this regression are consistent with this claim: those for on base percentage are more than twice as large as the coefficients for slugging.

III. The Labor Market's Valuation of Skill and the Athletics' Management Strategy

A. Valuation of Batting Skill in Baseball

In Scully's (1974) seminal model of pay and performance in baseball, a player's marginal revenue product is solely derived from his contribution to team winning percentage. The

[5] We have verified that on-base percentage, slugging percentage and OPS are useful measures of productivity by comparing their explanatory power with that of a more comprehensive measure, the "player game percentage," or PGP (Bennett and Fleuck, 1984, building on Lindsey, 1961). PGP is constructed by differencing win probabilities before and after an event, and thus directly measures the influence of each play on a team's chance of winning. We found that a team's aggregate PGP* (using the average PGP value for each event) predicted team winning percentages slightly better than both OPS, and its separate components. The PGP* model had an R^2 of 0.89 vs. 0.87 for the OPS model. PGP* is thus a better predictor, but this is not surprising given its comprehensive nature. While in some respects PGP is ideal, it requires play-by-play data to calculate. The effort required for PGP* to modestly out-perform OPS suggests that the simple measure has its virtues in applications such as the one explored here. For other questions, use of play-by-play data and state-specific probabilities is of paramount importance (Bennett, 1993; Hakes and Sauer, 2004, 2005), but this level of detail is not required here. Note that very accurate play by play data (i.e. extensively cross-checked and validated) is now available; see the note to Table 1.

final column of Table 1 demonstrates that a one point change in team on base percentage makes a significantly larger contribution to team winning percentage than a one point change in team slugging percentage. As an individual player's attempts constitute similar shares of all team offensive percentage statistics, an efficient labor market would (ceteris paribus) reward on base percentage and slugging percentage in the same proportions that those statistics contribute to winning.

We assess this proposition by estimating earnings equations for position players for the 2000-2004 seasons. The dependent variable is the logarithm of annual salary. All productivity variables are calculated based on performance in the prior year, and all players with more than 130 at bats in the previous season are included in the regressions.[6] The specification follows that of Lawrence Kahn (1993), and includes indicator variables for labor market status. The base category is for younger players who have limited negotiating power under the collective bargaining agreement. Indicator variables reflect competitive bidding conditions for players eligible for arbitration and free agency, respectively. Other relevant control variables include playing time, as measured by plate appearances, and indicator variables for the more demanding defensive positions of catcher and infield. Following Kahn (1993), we define an infielder as a player with a primary defensive position at either second base, third base, or shortstop.[7]

[6] Since salary is determined prior to performance and is based on expected productivity, we use the prior year's performance as an indicator of expectations. A minimum of 130 at bats is required for a player to qualify for honors as rookie of the year. This provides an objective cutoff so that we employ productivity measures exclusively for players with a large sample of at bats. As data on long-term contracts is not comprehensive, and long-term contracts introduce inertia to salary corrections, our regressions present a conservative test of the hypothesis. Changes in returns to a particular skill dimension across time would occur more slowly in our sample than in a counterfactual sample populated exclusively with one-year contracts. Position players are all players other than pitchers and designated hitters.

[7] Productivity and positional data were obtained from the Lahman baseball database at the Baseball Archive, http://baseball1.com. Data on salaries and labor market status were obtained from Doug Pappas' Business of Baseball data archive, http://roadsidephotos.sabr.org/baseball/data.htm.

The first column of results in Table 2 reports coefficient estimates from the log salary regression when all five years of data are pooled. All significant coefficients have the expected signs. There are large positive returns to contracting freedom. We estimate an incremental return to arbitration-eligible players relative to those subject to monopsony bargaining, and a still greater return for free agents. We also obtain positive and statistically significant returns to expected playing time. The returns to on base percentage and slugging are both positive, as expected. However, the coefficient for slugging is significantly greater than the coefficient for on base percentage, which is the reverse of their importance to team success. This is consistent with *Moneyball's* claim that on base percentage is undervalued in the labor market.

Columns 2 through 6 of Table 2 display parameter estimates for the same equation for each individual season. These results indicate that pooling is inappropriate, as labor market returns to player attributes appear to differ across seasons. This is clearly the case for the estimated returns to on base percentage and slugging percentage, as Figure 1 illustrates.

In the first four years of data, the slugging coefficients are all statistically significant and of similar magnitude, ranging between 2.05 and 3.10. In contrast, the on base percentage coefficients are smaller than their slugging counterparts (between –0.13 and 1.36) in each of these years and are not significantly related to log salary. The lack of a market premium for hitters with superior skill at reaching base validates the Athletics' systematic approach to identifying such players, and thereby winning games at a discount relative to their competition.

The relative valuation of on base and slugging percentage is abruptly reversed for the year 2004, despite the inertia produced by long-term contracts. The returns to slugging are similar in 2004 to prior years, but this is the first year for which the ability to reach base is statistically significant. The labor market in 2004 appears to have substantially corrected the apparent inefficiency in prior years, as the coefficient of on base percentage jumps to 3.68, and the ratio of the monetary returns to reaching base and slugging is very close to the ratio of the statistics' contributions to team win percentage.

We have thus verified a central claim in *Moneyball* by showing that on base percentage was undervalued at the beginning of the 2000-2004 period in Major League Baseball. But was the A's success due to a strategy which capitalized on this mis-pricing of skill, as Lewis alleged? Steven Levitt (2005) questioned this claim: "My contention is that the secret to Oakland's success has little to do with the things described in *Moneyball*, such as the emphasis on finding the skills in baseball that are good at producing runs, but not properly valued by the market. ...Oakland has been successful because they have great pitchers and because they have had good hitters (who look a whole lot like the good hitters on other good teams)."

The second part of Levitt's claim simply describes the facts - the A's aggregate offensive production looks very similar in nature to that of the other top teams in the league during this period, and they owed much of their success to great pitching. But the A's achieved these results by spending significantly less than their competitors. The question is how they got away with it. Did the A's just get lucky? We address these points in turn.

B. Efficiency and Management Strategy in the A's Personnel Decisions

The Athletics management strategy, as reported by Lewis (2003, p. 124) was to minimize the payroll required to build a team which would successfully contend for a playoff spot. Figure 2 is a scatterplot of team salaries and winning percentage which demonstrates the Athletics' ability to win "on the cheap." As Major League Baseball salaries were increasing rapidly during this period, each team payroll is indexed to the league-wide average for that season. The points in the scatterplot which represent the Athletics teams (OAK99 – OAK03) are tightly clustered in the bottom right corner of Figure 2, which is consistent with the Athletics' stated optimal combination of high winning percentage and low indexed team salaries.[8] Other teams along the "frontier" of efficiently converting payroll into wins usually either failed to have enough on-field success to make the playoffs (e.g., the 2003 Tampa Bay Devil Rays, 2000 Florida Marlins, and 2001 Minnesota Twins), or, like the 2001 Seattle Mariners, were far better on the field than their nearest competition during the regular season.[9]

The A's were able to purchase on base percentage cheaply through their emphasis on taking walks. Disciplined hitters avoid swinging at balls, forcing a pitcher to throw strikes to get an out. A reputation for discipline thus rewards a team with more pitches in the strike zone, i.e. easier pitches to hit. Discipline adds to on base percentage both

[8] As discussed in Lewis (2003, xiii), the late Doug Pappas (at that time chairman of SABR's Business of Baseball Committee) was one of the first to examine the efficiency with which the As' went about their business. Pappas calculated the incremental cost of winning a game during this period. Only two teams spent less than $1m to win a game. The As' cost of about half a million dollars was the lowest, and about 1/6 the cost of the least efficient teams. Pappas (2002) discusses the calculation and provides cost estimates for all teams during the 2001 season.

[9] It is instructive to note that as the market corrected, the Athletics remained near the frontier of salary efficiency, but their advantage was narrowed. Despite increasing their payroll to 86% of league average, they finished one game behind the Angels in 2004, missing the playoffs for the first time since 1999.

through the additional walks generated, and the secondary effect of seeing more pitches capable of being hit successfully.

Discipline in taking pitches was a central theme of player development in Oakland beginning in the mid-90s. Consider this quote from third baseman Eric Chavez: "The A's started showing me these numbers [...] how guys' on-base percentages are important. It was like they didn't want me to hit for average or for home runs, but walks would get me to the big leagues (Lewis, 2003, p. 151)." And later on the same page, Lewis reports Miguel Tejada, who won the 2002 American League Most Valuable Player Award, as saying (presumably half-joking), "If I don't take twenty walks, Billy Beane send me to Mexico."

The emphasis on taking walks is apparent in the A's aggregate batting statistics. They led the American League in walks in 1999 and 2001, were second or third in 2000, 2002, and 2004, and fifth in 2003.[10] Coupled with the emphasis on walks in player development, this success suggests that an explicit strategy was being followed.[11]

Personnel movements during these years illustrate how the Athletics' found inexpensive parts to maintain team success when individual players became too expensive to keep. When 2000 AL MVP slugger Jason Giambi qualified for free agency following the 2001 season, Oakland let him go. After making $4.1 million in 2001, Giambi signed a seven-year contract with the New York Yankees for $120 million dollars. To fill the hole in the lineup, Oakland signed a catcher with a good batting eye

[10] Source: http://www.baseball-reference.com/leagues/AL.shtml.

[11] Oakland's strategy of finding undervalued players and locking them up for bargain prices extended to pitchers as well. The current ace of the Oakland staff, Barry Zito, was passed over by both the Texas Rangers and San Diego Padres, who told him that he "didn't throw hard enough to make it in the big leagues" (Lewis, 2003, p. 221). Oakland's scouting department agreed, but Beane drafted Zito anyway, obtaining six years of excellent work from a pitcher that would win the Cy Young award, at bargain prices.

but a damaged arm, Scott Hatteberg, to play first base, and made up the lost production by upgrading their lineup at two other positions. They took a chance on David Justice, who had a high on-base percentage, but whose market value was reduced due to age concerns, and signed Jeremy Giambi, who was avoided by other teams due to a lack of speed. To take advantage of his ability to reach base, Jason's younger brother became the Athletics' leadoff batter despite being "the slowest man on the slowest team in professional baseball.(Lewis, 2003, p. 142)." With three misfit parts added to replace the lost superstar, the Athletics repeated as division champions in 2002, actually improving their record by one win. The replacement of offensive production from a now expensive Jason Giambi, with an array of undervalued talent neatly encapsulates Lewis' argument, and ours.

IV. Concluding Remarks

Our analysis supports the hypothesis that baseball's labor market was inefficient at the turn of the twenty-first century. Exploitation of this inefficiency by the Oakland Athletics' organization is traced by Lewis (2003, pp. 58-63) to an explicit decision, inspired by the work of Bill James, to fuse statistical analysis of the game into a management strategy. To execute this strategy, the A's reached outside baseball circles and hired talented young analysts with Ivy League pedigrees and an interest in the game.

The particular margin of inefficiency emphasized in Moneyball, undervaluation of a batter's ability to get on base, appears to have been substantially if not completely eroded by the time the book was published. Despite protests from baseball traditionalists

(Lewis, 2004) that the book was somehow misguided, several major league teams had by this time decided to imitate the strategy.

During and after the 2003 season, two young analysts from the Athletics' front office were hired as General Managers by the Toronto Blue Jays and the Los Angeles Dodgers (Joe Saraceno, 2004).[12] Although the Boston Red Sox failed in their attempt to hire both the Athletics' General Manager (Billy Beane) and Assistant GM, they followed Beane's advice by hiring Theo Epstein, making him the youngest GM in baseball history (Shaughnessy, 2003). In addition, the Sox hired the father of sabermetrics, Bill James himself, in an advisory capacity. This diffusion of statistical knowledge across a handful of decision-making units in baseball was apparently sufficient to correct the mis-pricing of skill.

Finally, we close on a humble note. Our work is essentially an assessment of Lewis' argument, and as such is merely an after-the-fact replication of work done by the innovators at the heart of his book. But we do find that they (and Lewis) were right, and further, that an adjustment process set off by their strategy had in large part been completed by the time the book was published. That the addition of only a few individuals was able to correct a long-standing anomaly illustrates both the inefficiency which can result when markets are isolated from competition, and the swiftness of market corrections once entry occurs.

[12] For most franchises, the General Manager is the executive with authority over personnel decisions.

Table 1 – Productivity Estimates:
The Impact of On Base and Slugging Percentage on Winning

	Model			
	1	2	3	4
Constant	0.506	0.593	0.558	.500
	(0.087)	(0.066)	(0.073)	(0.002)
OPS			1.261	
			(0.061)	
OPS Against			-1.337	
			(0.055)	
On Base	3.297			2.032
	(0.189)			(0.180)
On Base Against	-3.315			-2.032^{R}
	(0.171)			
Slugging		1.753		0.900
		(0.116)		(0.105)
Slugging Against		-1.971		-0.900^{R}
		(0.107)		
Number of Observations	150	150	150	150
R^2	.825	.786	.871	.882

Hypothesis Test of Model 4, H^0: On Base = Slugging
F(1, 147) = 17.21, p-value = 0.0001

Notes: Data are aggregate statistics for all 30 teams from 1999-2003. Coefficient estimates obtained using OLS. Standard errors are in parentheses; The superscript R indicates the coefficient was restricted to equal its counterpart in the regression. p-value for null hypothesis that restrictions are valid: 0.613 (F = 0.49).

Data Source: Retrosheet Game Logs, www.retrosheet.org. This data was obtained free of charge from and is copyrighted by Retrosheet. Interested parties may contact Retrosheet at 20 Sunset Rd., Newark, DE 19711.

Table 2 – The Baseball Labor Market's Valuation of On Base and Slugging Percentage

	All Years	2000	2001	2002	2003	2004
On Base	1.360	1.334	-0.132	0.965	1.351	3.681
	(0.625)	(1.237)	(1.230)	(1.489)	(1.596)	(1.598)
Slugging	2.392	2.754	3.102	2.080	2.047	2.175
	(0.311)	(0.628)	(0.613)	(0.686)	(0.850)	(0.788)
Plate Appearances	0.003	0.003	0.003	0.003	0.003	0.003
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Arbitration Eligible	1.255	1.293	1.106	1.323	1.249	1.323
	(0.047)	(0.102)	(0.100)	(0.100)	(0.111)	(0.115)
Free Agency	1.683	1.764	1.684	1.729	1.663	1.575
	(0.044)	(0.096)	(0.092)	(0.097)	(0.107)	(0.105)
Catcher Dummy	0.152	0.137	0.065	0.208	0.343	0.059
	(0.056)	(0.124)	(0.116)	(0.122)	(0.134)	(0.133)
Infielder Dummy	-0.029	0.060	0.069	-0.087	-0.054	-0.100
	(0.040)	(0.087)	(0.083)	(0.086)	(0.095)	(0.098)
Intercept	10.083	10.078	10.347	10.490	10.289	9.782
	(0.170)	(0.360)	(0.321)	(0.358)	(0.387)	(0.414)
Number of observations	1736	353	357	344	342	340
R^2	0.675	0.676	0.728	0.695	0.655	0.635

Notes: The dependent variable is ln(Salary) for year t, and performance variables are from year t-1. 0/1 dummies for each year are included in the pooled regression. Standard errors in parentheses. The sample includes all players with at least 130 plate appearances during the relevant season.

Source: Performance and position from the Lahman database v. 5.1, http://www.baseball1.com. Salaries and labor market status from Doug Pappas, http://roadsidephotos.sabr.org/baseball/data.htm.

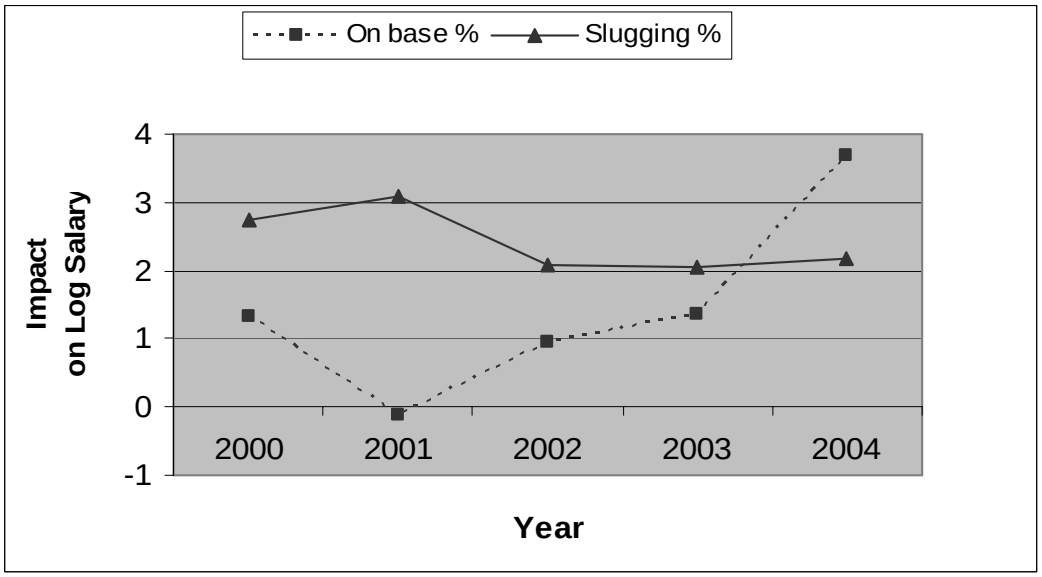

Figure 1. Labor Market Returns to On Base and Slugging Percentage Over Time

Source: Coefficient estimates from Table 2

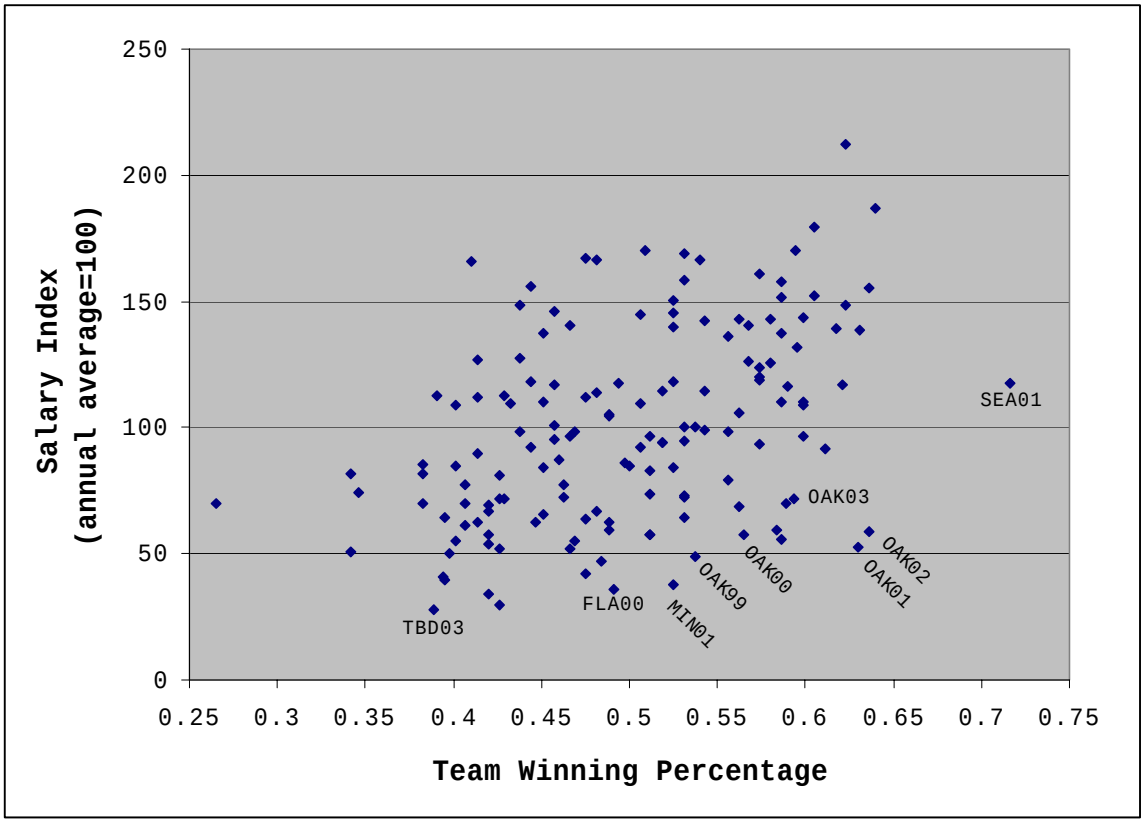

Figure 2. Frontier for Efficient Conversion of Team Salary into Team Winning Percentage, 1999-2003

Source: Won-loss records from www.baseball-reference.com. Team salaries from SABR, http://businessofbaseball.com/data.htm.

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